

Applied nutritional investigation

Assessment of change in hydration in women during pregnancy and postpartum with bioelectrical impedance vectors

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Abstract

Objective: This study tested the hypothesis that bioelectrical impedance vectors, group and individual, are valid indicators of total body water (TBW) and hydration status in women experiencing fluid gain and loss during and after pregnancy.

Methods: We measured TBW, assessed with D₂O dilution, and resistance (R) and reactance (Xc), determined with 800 μ A at 50 kHz and standardized for height (H) and plotted on a bivariate (R-Xc) graph, in 15 women, 21–37 y of age, longitudinally before and during pregnancy and postpartum (PP).

Results: Body weight (61.9 ± 2.3 to 75.5 ± 2.3 kg) and TBW (31.4 ± 1.1 to 38.2 ± 1.1 L) increased ($P < 0.05$) from before pregnancy to the third trimester of pregnancy and decreased PP (67.0 ± 2.3 kg and 32.7 ± 1.1 L, $P < 0.05$). R/H and Xc/H decreased during pregnancy ($P < 0.05$, 361 ± 10 to 318 ± 10 and 44 ± 1 to 36 ± 1 ω /m, respectively) and increased PP ($P < 0.05$, 355 ± 10 and 41 ± 1 Ω /m). Vector length decreased ($P < 0.05$, 363 ± 10 to 320 ± 10 Ω) during pregnancy and increased PP ($P < 0.05$, 357 ± 10 Ω). Changes in vector length and TBW during pregnancy and PP were correlated ($r = -0.599$, $P < 0.001$). Women with vectors exceeding a 75% tolerance interval had greater TBW gain (10–12 versus 5–6 L) during pregnancy compared with other women with vectors within this tolerance level.

Conclusion: These findings indicate that impedance vectors provide quantitative evidence of hydration status during pregnancy and that the impedance vector method is useful in monitoring hydration status in pregnancy. © 2007 Elsevier Inc. All rights reserved.

Keywords:

Total body water; Impedance; Pregnancy; Human

Introduction

Pregnancy is a physiological condition in which marked increases in body weight and composition occur during a brief period [1]. Gestational body weight gain includes fat deposition, total body water (TBW) buildup, and growth of the products of conception [2]. Changes in body composition during pregnancy have been associated with adverse

maternal and fetal outcomes. Although guidelines for weight gain during pregnancy are available [2], information describing the effect of changes in body fat and water on pregnancy outcome is limited. In general, fat gain is inversely related to body mass index (BMI) in successful term pregnancies [3]. Recent findings have suggested that excessive increases or failure to increase TBW volume are associated with adverse pregnancy outcomes [4,5].

Cross-sectional [6–9] and longitudinal [10–12] studies have described a pattern of increased TBW determined with isotope dilution during successful pregnancies. Recent observational studies, however, have estimated TBW with bioelectrical impedance methods and linked differences in volumes of TBW with health problems of mothers during pregnancy [4,5,13–15]. These cross-sectional studies only described group differences in TBW volumes in relation to morbidity (e.g., maternal hypertension or edema) but pro-

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vided no prognostic indicators of risk of an adverse outcome for an individual.

An alternative approach that can provide an individual assessment of hydration status is bioelectrical impedance vector analysis. Measurements of resistance (R) and reactance (Xc), determined using 800 μ A of alternating current at 50 kHz and standardized for standing height (H), and plotted on a bivariate graph (R-Xc graph) yield a vector of length and direction [16]. Group and individual impedance vectors have been used to characterize differences between groups of healthy subjects and patients with altered fluid status. Vectors of patients before dialysis are significantly shorter with a downward orientation than after dialysis [17]. Also, individual vectors of predialytic patients are located in the lower half of tolerance intervals developed in healthy age- and sex-matched individuals [17,18]. An advantage of the vector approach is the lack of reliance on regression models to predict TBW and the inherent error [19] associated with the use of group models to predict individual TBW values.

This study examined the validity of bioelectrical impedance vectors to assess TBW in women longitudinally before, during, and after pregnancy and to discriminate excess fluid accumulation with the R-Xc graph. It tested the hypotheses that changes in impedance vector length are significantly related to measured changes in TBW and that individual vectors characterized as outside of normal hydration status are associated with increased TBW accumulation.

Materials and methods

Subjects

Fifteen women, 11 primigravidae and 4 multigravidae, 21 to 37 y of age with a prepregnancy BMI of 18 to 30 kg/m² and standing height of 159.1 to 181.0 cm, participated in this study. The women were recruited with print advertisements while they were planning to become pregnant. Each woman gave written informed consent before participation in the study, which was approved by the University of North Dakota institutional review board and the U.S. Department of Agriculture Human Study Committee. The women received medical clearance before participating in any testing. All the women had normal, full-term pregnancies and delivered single healthy infants of normal weight for gestational age.

Design

Each woman participated in body composition assessment before pregnancy at regular intervals unless she missed a menstrual period. All women reported the duration of usual menstrual activity to be a 26- to 40-d cycle. If a woman failed to menstruate within the expected time based

on her usual experience, she had a pregnancy test. If the test was positive, the woman was scheduled to repeat testing every 90 d. Pregnancy was documented with a positive plasma human chorionic gonadotropin test. Data from the test date closest to the objective determination of pregnancy were used for prepregnancy. Based on delivery date, trimester test dates were also calculated. On average, there was a 12- to 14-wk duration between the time of the last prepregnancy and first-trimester body composition test. Body composition was assessed approximately at 14, 26, and 36–38 wk of gestation. The women also were scheduled for postpartum testing at 8–10 wk after delivery. All women were lactating at the time of the postpartum testing.

Total body water

The women came to the laboratory in the morning after an overnight fast (~8 h). Standing height and body weight were measured in minimal clothing and without shoes with a wall-mounted stadiometer (Harpندن, Pembrokeshire, United Kingdom) and a calibrated scale (model 2831; Toledo Scale, Worthington, OH, USA), respectively.

Total body water was measured by deuterium dilution. Each woman drank 10–15 g of D₂O (99.9% purity; Cambridge Isotopes, Cambridge, MA, USA) mixed with 350 mL of distilled deionized water. Venous blood samples were obtained before and 4 h after ingestion of the deuterium mixture. All urine excreted during the 4-h equilibration period was collected and analyzed for deuterium concentration. After vacuum sublimation, plasma and urine water samples were analyzed in triplicate for deuterium concentrations by using fixed-filter infrared spectroscopy [20]. The analytical precision and accuracy were 2.5% [20]. The deuterium dilution space (DDS) was calculated by using the retained deuterium (amount administered [grams] – amount lost in the urine during equilibration [grams]) divided by the 4-h plasma deuterium concentration (grams per liter). TBW (liters) was calculated from the DDS by assuming a 4% overestimation of TBW from the DDS because of deuterium-hydrogen exchange [21].

Hematocrit was determined by using an aliquot of the fasting venous blood obtained before the ingestion of deuterium. Hematocrit was measured by using a standard method and instrumentation (Coulter model S-Plus; Coulter Electronics, Hialeah, FL, USA).

Bioelectrical impedance

Measurements of R and Xc were made with a tetrapolar impedance plethysmograph (model 101; RJL Systems, Clinton Township, MI, USA) as described by Lukaski et al. [22]. Each woman wore standard clothing (e.g., scrubs) but no shoes or socks and was supine on the surface of a table made of non-conductive materials for 20 min before measurements of R and Xc. Aluminum

foil, adhesive electrodes (M6001; Contact Products, Dallas, TX, USA) were cut to a constant length (3.8 cm, or 1.5 inches) and placed on the dorsal surfaces of the right hand and foot after the even application of electrocardiographic paste on the conductive surface of each spot electrode in contact with the skin [22]. An 800- μ A alternating current at 50 kHz was introduced into the distal electrodes, and R and Xc were determined at the proximal electrodes. Phase angle was calculated as $\arctan(Xc/R)$. Accuracy of the measurements, determined before each impedance test with a calibration circuit of known impedance value ($R = 450 \Omega$ and $Xc = 65 \Omega$), was $\pm 1\%$. The mean coefficient of variation was $<1\%$ for within-day and $<2\%$ for between-day intraindividual measurements determined in another group of volunteers.

Impedance vectors

Group or average vectors and individual impedance vectors for each woman were plotted on an R-Xc graph [16]. The length of each vector was calculated as the hypotenuse of individual impedance values. To evaluate changes in hydration status through gestation and postpartum, group impedance vectors and ellipses (95% confidence intervals) were plotted and compared with the prepregnancy 95% ellipse. Individual impedance vectors during the third trimester were plotted on the bivariate distribution (50%, 75%, and 95% tolerance intervals) of a reference group vector derived from a population of 98 healthy Caucasian women who were neither pregnant nor lactating, 18 to 40 y of age with body weight of 48 to 97 kg and BMI of 16 to 32 kg/m², who were participating in other studies, and measured generally under the same conditions. The confidence or tolerance ellipses were calculated with the standard method [16] by using bioelectrical impedance vector software (A Piccoli, Department of Medical and Surgical Services, University of Padova, Padova, Italy; available by request at apiccoli@unipd.it). Vectors of individuals outside the 75% tolerance ellipses were considered to indicate altered hydration [17].

Statistical analyses

Data are presented as mean \pm SE. An all pairwise comparison of body weight, TBW, and impedance variables before and during pregnancy and postpartum was performed with repeated measures analysis of variance by using the PROC MIXED procedure in SAS 9.1 (SAS Institute, Cary, NC, USA). When the main effect of stage of pregnancy was significant, pairwise differences were assessed by using Tukey-Kramer contrasts (SAS Institute). The relation between impedance vector length and TBW and changes in these parameters were investigated by using a linear mixed effects model and fitted using PROC MIXED in SAS. In the model used, volunteer was treated as a random effect and an unstructured variance-covariance matrix was specified. This

method accounts for the repeated measurements on each individual over time [23].

Differences in the distribution of R/H and Xc/H means across pre-pregnancy, pregnancy (each trimester) and postpartum were jointly tested by using repeated measures multivariate analysis of variance using PROC GLM in SAS. Only women who completed all tests ($n = 12$) were included in this analysis. Because the effect of time was statistically significant ($P < 0.0006$), single degree-of-freedom multivariate contrasts were done comparing each trimester and postpartum with prepregnancy. Changes in R/H and Xc/H values were calculated for each subject ($n = 12$) by subtracting their prepregnancy values from the values measured at each trimester. Differences in the distribution of the change in R/H and change in Xc/H across the three trimesters were jointly tested by using repeated measures multivariate analysis of variance. Because the effect of time was statistically significant ($P = 0.001$), single degree-of-freedom multivariate contrasts were done comparing trimesters 2 and 3 with trimester 1.

Results

Changes during pregnancy and postpartum

Compared with prepregnancy values, body weight increased significantly during the second and third trimesters (Table 1). Postpartum weight was significantly less than in the third trimester and significantly greater than prepregnancy values (Table 1). Similarly, TBW progressively increased ($P < 0.05$) after the first trimester and decreased significantly postpartum compared with the third trimester; postpartum TBW was not different from the first- and second-trimester or prepregnancy values. Hematocrit decreased significantly in the second and third trimesters and increased significantly postpartum compared with prepregnancy values.

Resistance and Xc, absolute values and standardized for height, decreased significantly at the third trimester compared with other times and returned to prepregnancy values postpartum (Table 1). R and Xc were significantly correlated at each measurement period. Phase angle did not change significantly during pregnancy and postpartum. Vector length decreased significantly during the third trimester compared with prepregnancy and increased significantly postpartum to prepregnancy values.

Vectors as predictors of TBW

Vector length was significantly related to TBW across all stages ($r = -0.790$, $P < 0.0001$; Fig. 1). Changes in vector length and changes in TBW also were significantly related ($r = -0.599$, $P < 0.001$; Fig. 2).

Table 1

Physical and body compositional characteristics of women before, during, and after pregnancy*

	Before pregnancy	First trimester	Second trimester	Third trimester	Postpartum
No. of subjects	15	13	15	14	15
Weight (kg)	61.9 ± 2.3 ^a	62.1 ± 2.3 ^a	69.2 ± 2.3 ^b	75.5 ± 2.3 ^c	67.0 ± 2.3 ^b
Total body water (L)	31.4 ± 1.0 ^a	30.8 ± 1.1 ^a	34.5 ± 1.0 ^b	38.2 ± 1.1 ^c	32.7 ± 1.0 ^{ab}
Hematocrit (L)	0.39 ± 0.07 ^{ab}	0.37 ± 0.07 ^{bc}	0.36 ± 0.07 ^c	0.36 ± 0.07 ^c	0.41 ± 0.07 ^a
Resistance (Ω)	600 ± 16 ^{ab}	607 ± 17 ^a	577 ± 17 ^b	530 ± 17 ^c	590 ± 17 ^{ab}
Reactance (Ω)	73 ± 2 ^a	70 ± 2 ^a	66 ± 2 ^{ab}	60 ± 2 ^b	69 ± 2 ^a
Resistance/height (Ω/m)	361 ± 10 ^{ab}	365 ± 10 ^a	347 ± 10 ^b	318 ± 10 ^c	355 ± 10 ^{ab}
Reactance/height (Ω/m)	44 ± 1 ^a	42 ± 1 ^a	40 ± 1 ^{ab}	36 ± 1 ^b	41 ± 1 ^a
Phase angle (°)	7.0 ± 0.2	6.6 ± 0.2	6.6 ± 0.2	6.5 ± 0.2	6.6 ± 0.2
Vector length (Ω)	363 ± 10 ^{ab}	367 ± 10 ^a	349 ± 10 ^b	320 ± 10 ^c	357 ± 10 ^{ab}
r^{\dagger} (reactance, resistance)	0.61	0.72	0.66	0.86	0.65

* Values are means ± pooled SEs. Values with different superscript letters are significantly different ($P < 0.05$) by Tukey-Kramer contrasts.[†] Correlation coefficient ($P < 0.05$).

Group vectors

Compared with the prepregnancy group vector, vector lengths decreased significantly during gestation (Fig. 3A–C). The displacement of the vectors compared with prepregnancy was downward during the second ($P < 0.007$) and third ($P < 0.0002$) trimesters of pregnancy; it was affected by significant decreases in R/H during the second ($P < 0.02$) and third ($P < 0.0001$) trimesters, a significant decrease ($P < 0.02$) in Xc/H in the third trimester, with no change in phase angle. The mean postpartum vector was similar to the prepregnancy vector (Fig. 3D).

Differences in the distribution of relative changes in R/H and Xc/H throughout pregnancy compared with prepregnancy were found (Fig. 4). The change in group vector from the first to the second trimester was different ($P < 0.001$) as was the change from the first to the third trimester ($P < 0.0004$).

Individual vectors

To evaluate the ability of impedance vectors to discriminate excess fluid accumulation, Figure 5 shows the placement of individual impedance vectors from the third trimester compared with the percentile distribution of vectors derived in healthy Caucasian women previously studied at the center. Fluid accumulation was characterized by vectors outside the 75% tolerance interval [17]. Women ($n = 2$) whose vectors were outside the 75% tolerance interval had TBW gains, calculated as third trimester minus prepregnancy values, that ranged from 10 to 12 L compared with the 5- to 6-L gain in the women whose vectors were within the 75% tolerance interval for normal hydration. These changes resulted in 55% and 72% increases in the TBW to weight gain in the normally hydrated and overhydrated women, respectively.

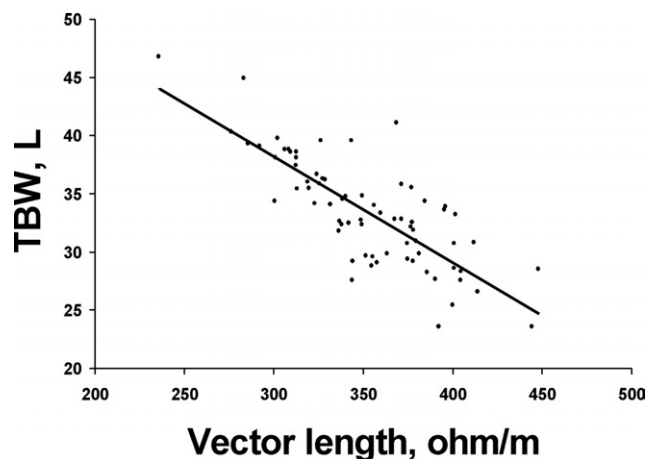


Fig. 1. Relation between vector length and TBW in women before, during, and after pregnancy ($n = 72$, $r = -0.79$, $P < 0.0001$) TBW, total body water.

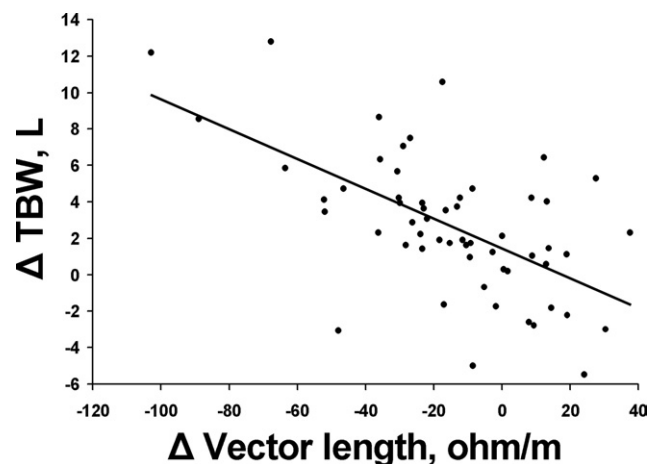


Fig. 2. Correlation of Δ in vector length and in TBW in women during and after pregnancy ($n = 57$, $r = -0.559$, $P < 0.001$). Δ , change; TBW, total body water.

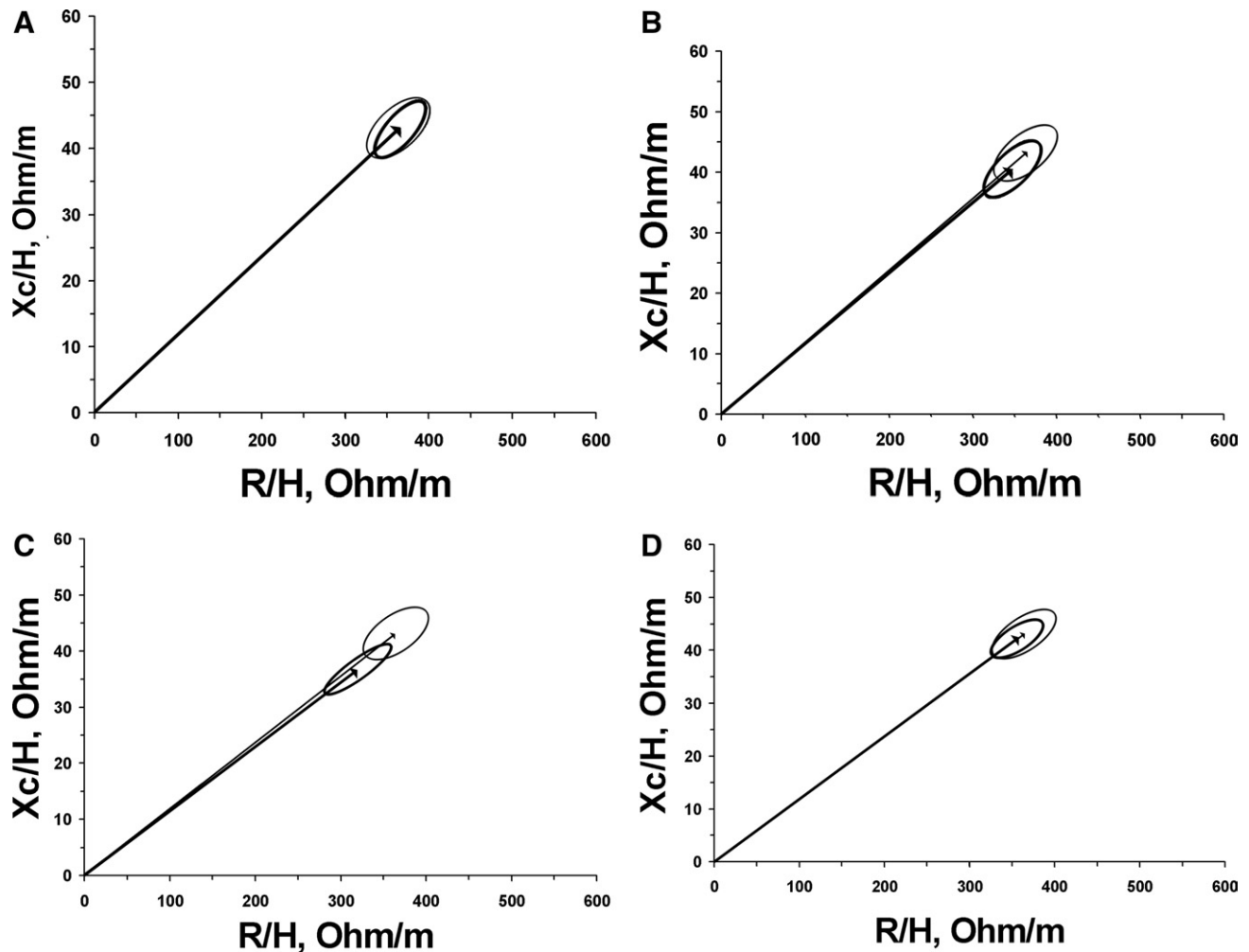


Fig. 3. Mean vectors with 95% confidence intervals of women ($n = 12$) before, during, and after pregnancy. Panels show prepregnancy (light ellipse) compared with trimester 1 (A), trimester 2 (B), trimester 3 (C), and postpartum (D) shown each in a dark ellipse. Compared with prepregnancy, trimesters 2 ($P < 0.007$) and 3 ($P < 0.0002$) are significantly different by repeated measures multivariate analysis of variance. H, height; R, resistance; Xc, reactance.

Discussion

Routine, non-invasive assessment of hydration status is problematic in individuals with fluid accumulation associated with physiologic conditions such as pregnancy. The impracticality (cost of equipment and inconvenience for the participant) of isotope dilution and the imprecision of impedance prediction of body water volume for an individual limit the use of these methods in clinical practice. The lack of TBW volume criteria for diagnosis of over- and under-hydration further restricts the general use of these techniques. An approach that overcomes these practical restrictions is bioelectrical impedance vector analysis [16]. Although the impedance vector method has been used to distinguish hydration status of patients with severely altered fluid status (e.g., excessive fluid accumulation), albeit with limited validation [18], its application in patients with modest fluid accumulation is lacking. The present study examined the validity of impedance vectors to assess hydration changes. It demonstrated that impedance vectors were significantly cor-

related with isotope dilution determinations of TBW in women with fluid gain during pregnancy and loss postpartum, and that changes in these parameters were significantly related. Also, in comparison with a reference distribution of impedance components in healthy women, impedance vectors successfully identified women with excessive fluid gain during pregnancy.

Increases in body weight during gestation predominantly reflect the relative expansion of TBW volume with water to weight gain of 60% to 70% [2,24]. Fluid increases occur principally in the extracellular compartment because of an expansion in plasma volume [25,26] and concomitant increase in blood volume, without an increase in red blood cell mass [25]. These changes are a necessary adaptation to accommodate hemodynamic changes required to boost maternal cardiac output and to support placental function, fetal growth, and development.

Altered hydration during pregnancy has been associated with adverse maternal and fetal outcomes. Excessive expansion of TBW volume can result from edema and cause

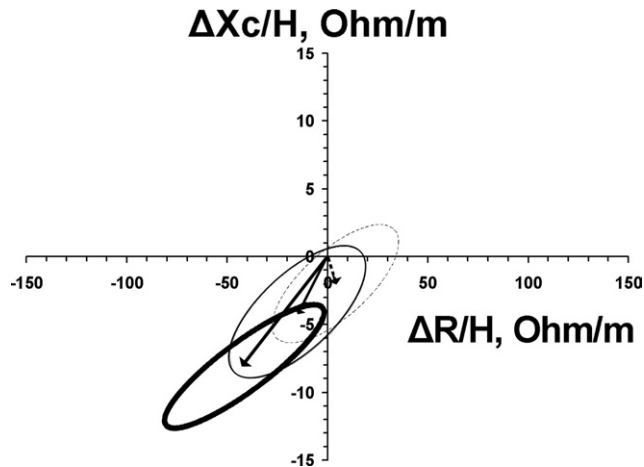


Fig. 4. Mean changes in position of impedance vectors and 95% confidence intervals of Δ in R/H and Δ in Xc/H (trimester 2 or 3 minus trimester 1) in women ($n = 12$). Compared with trimester 1 (dashed-line ellipse), trimester 2 (thin-line ellipse; $P < 0.001$) and trimester 3 (dark-line ellipse; $P < 0.0004$) are significantly different by repeated measures multivariate analysis of variance. Δ , change; H, height; R, resistance; Xc, reactance.

hypertension [5]. A progressive reduction in TBW during gestation has been linked to gestational hypertension and pre-eclampsia [13,15] and to low birth weight and poor pregnancy outcome [27,28]. Thus, regular assessment of hydration status is important to envisage potential health problems of pregnant women.

The safe, convenient, rapid, and non-invasive characteristics of the impedance method facilitated some applications during pregnancy. Early studies evaluated the validity of different impedance approaches to assess TBW and extracellular water during pregnancy and postpartum. Single-frequency (50-kHz) impedance measurements, anthropometric variables (height, weight, and abdominal circumference), and hematocrit were included in a multiple variable regression model to predict TBW that was validated during pregnancy and postpartum [10]. In contrast, bioelectrical impedance spectroscopy yielded inconsistent results. One study found no significant difference between predicted and measured values [11], whereas another study reported significant underestimation of the changes in TBW and its distribution during pregnancy and postpartum [12].

The impedance method also has been used in observational studies of some complications during pregnancy. Women with hypertension and pre-eclampsia during the third trimester had significantly greater impedance indices (H^2/R at 50 kHz), which are indicative of increased TBW volumes [22], compared with other pregnant women without these perturbations [4,5]. Similarly, women with gestational hypertension and pre-eclampsia had significantly larger predicted TBW volumes than other women who did not develop hypertension during pregnancy [14,15]. Although these findings suggest the potential value of 50-kHz impedance to estimate altered hydration during pregnancy,

they neither confirmed the predicted TBW volumes nor distinguished the women who gained excessive water.

The present study provides the first validation of the impedance vector method to longitudinally monitor fluid gain and loss and to assess hydration status in humans. Use of impedance vectors to ascertain fluid status relies on empirical data showing directional displacements of group or individual vectors in response to treatment and in comparison with vectors derived in healthy sex-matched subjects. Attempts to validate impedance vectors have used clinical observation or predictions of fluid volumes from prediction equations [16,18,29]. Thus, use of impedance vectors to monitor changes in hydration requires validation with reference determinations of TBW.

Important observations of impedance vector patterns in patients with fluid overload are corroborated and expanded by the findings of the present study. TBW influences vector length. Patients with renal disease requiring dialytic therapy have larger TBW volume before compared with after hemodialysis, and the group vector is shorter because of lower R/H and Xc/H values. Conversely, fluid loss after dialysis is associated with an increase in vector length and is distinguished by an increase in R/H and Xc/H [16,18]. These general patterns in impedance components are confirmed by the findings of the present study in which TBW volumes increased significantly during pregnancy and were accompanied by significant decreases in R/H, Xc/H, and vector length. Furthermore, the measured decreases in TBW postpartum compared with the third trimester of gestation were accompanied by opposite changes in impedance variables and vector length. Importantly, the finding of greater relative change in Xc/H compared with R/H in the postdialysis patients with renal disease was also found in the data of the pregnant women from the third trimester to postpartum (18% versus 11%, respectively). Dominant changes in Xc/H have been designated as changes in body hydration [16,18]. These findings provide the first validation of the impedance vector approach to assess changes in TBW and hydration.

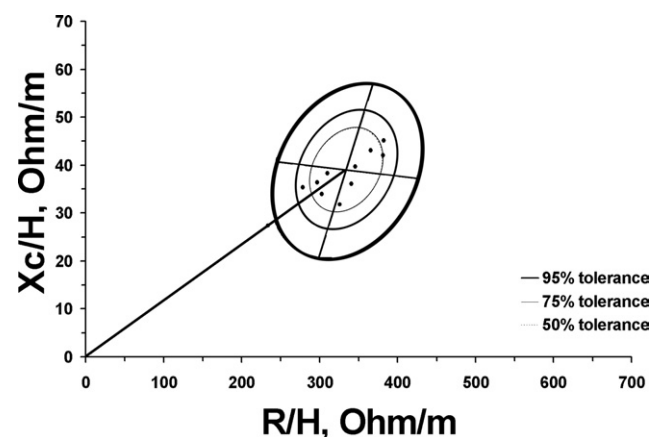


Fig. 5. Distribution of individual impedance vectors (points) during trimester 3 compared with reference tolerance (50%, 75%, and 95%) ellipses of healthy Caucasian women. H, height; R, resistance; Xc, reactance.

An essential point in the use of the impedance vector method to evaluate the hydration status of a clinical or interventional group is the choice of an appropriate healthy reference sample. Reports have indicated that factors such as age, sex, race, and BMI independently affect the position of the group vector and confidence interval of a reference sample on the R-Xc graph [30]. Although impedance data from two surveys are available, they should be viewed with some caution. Piccoli et al. [31] measured 372 healthy Italian women 18 to 82 y old and reported an R/H of $372 \pm 49 \Omega/\text{m}$ (mean \pm SD) and an Xc/H of $38 \pm 7 \Omega/\text{m}$ ($r = 0.41$). Data from the National Health and Nutrition Examination Survey (NHANES) III sample [30] included 1625 women with similar R/H data ($373 \pm 44 \Omega/\text{m}$) but greater Xc/H ($47 \pm 7 \Omega/\text{m}$; $r = 0.61$). This difference in the Xc/H data from the NHANES III sample is attributable to the use of an impedance device that did not directly measure Xc but was calculated from impedance and R [32]. Also, R values determined with this impedance instrument were significantly different (3 and 10 Ω for men and women, respectively) from the values determined in another sample of adults measured with an instrument similar to that used by Piccoli et al. [30,31] and in the present study [32]. Another measurement factor to consider is the conditions under which the impedance measurements were made. Description of data collection for the NHANES III and the Italian samples does not include information about timing of food and beverage intake before impedance measurement. Fasting for periods exceeding 4 h significantly increases R and Xc values [33]. Also, the surface area of an electrode, which was different in these surveys, significantly influences measurements of R and Xc [33].

In the present study, we used reference impedance data from healthy women ($n = 98$), 18 to 40 y old, collected without restriction of timing of food and beverage intake and found R/H ($334 \pm 39 \Omega/\text{m}$), and Xc/H ($39 \pm 7 \Omega/\text{m}$) and correlation of 0.27. Compared with the Italian reference sample [31], our reference mean vector and tolerance ellipse was displaced upward and to the left because of a decrease in mean R/H (372 versus 334 Ω/m) with similar mean Xc/H (38–39 Ω/m). The principal factor explaining the displacement upward and to the left is likely the difference in age of the reference populations, 18 to 40 y in the present study and 15 to 85 y, with a similar BMI range (16–31 kg/m^2) in Piccoli's population [18,29,31]. This age-dependent pattern of vector distribution has been documented in the NHANES III population [30].

Examination of individual vectors of the women determined during the third trimester of pregnancy revealed that two of the vectors were outside the 75% percentile of the reference sample (Fig. 5). Corresponding measured TBW volumes were larger than the other vectors within the 75% tolerance interval. This finding confirms the validity of bioelectrical impedance vectors to discriminate excess fluid accumulation. It is noteworthy that the two women whose vectors met or exceeded the 75% tolerance interval experi-

enced modest peripheral edema in late pregnancy. None of the women had signs of clinical edema including excessive fluid accumulation or hypertension. Also, all of the third-trimester vectors were located in the lower quadrant of the tolerance ellipses, which is consistent with the shorter vector lengths (Fig. 3A–D) and displacements parallel to the major axis of the reference ellipse. As summarized in a recent review, clinical evidence indicates that point vectors and vector trajectories spanning the left, compared with the right, side of ellipses are from humans with more compared with less soft tissue mass, respectively [34]. Women whose point vectors were found in the left side of the tolerance ellipses had greater increases in BMI during the third trimester than the other women.

In summary, findings from the present study demonstrate the validity of the impedance vectors to monitor changes in TBW during pregnancy and postpartum. In conjunction with a reference distribution of bivariate impedance vector components, this method is capable of discriminating individuals with excessive fluid gain. The practical characteristics of the impedance method suggest that its use in monitoring fluid status should be evaluated prospectively to determine its prognostic value in identifying women at risk for complications during pregnancy.

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